

HYDROELECTRIC PLANT  
ON MISSISSIPPI RIVER, MOLINE, ILLINOIS

BY

A. A. HEEREN  
J. C. VESELY  
W. OLDENBURGER

ARMOUR INSTITUTE OF TECHNOLOGY

1914

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Heeren, A. A.

Design of hydroelectric  
plant on Mississippi River,

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DESIGN OF HYDROELECTRIC PLANT

-on-

MISSISSIPPI RIVER, MOLINE, ILLINOIS.

A Thesis Presented by:

Arthur G. Heeren  
J. C. Vesely  
Wm. Oldenburger.

To

The President and Faculty  
of

Armour Institute of Technology

For the Degree of

Bachelor of Science in Civil Engineering

Having completed the Prescribed Course in

Civil Engineering.

Chicago, Illinois.

May 1914.

Alfred Phillips Prof. of Civil Eng.

E. V. Freeman Prof. of Elect. Eng.

J. M. Rappaport

L. C. Morin

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## INTRODUCTION.

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In presenting this thesis for approval by the Faculty of the Civil and Electrical Engineering Department of the Armour Institute of Technology, it has been the aim of the students to carry out as nearly as possible, present practice in the design of hydro-electric power stations.

Standard practice has been closely adhered to wherever possible, no attempt being made at original design in such things as machine parts and electrical equipment. All other designs, however, have been made according to the students' best knowledge.

It is not the intention of the students to present a complete and detailed design of the installation, but merely such a design as would prove of great use in promoting such a development and showing the feasibility of the project.

- The first stage of the process is the identification of the problem.
- The second stage is the identification of the causes of the problem.
- The third stage is the identification of the effects of the problem.
- The fourth stage is the identification of the solutions to the problem.
- The fifth stage is the implementation of the solutions.
- The sixth stage is the evaluation of the results.
- The seventh stage is the feedback loop.
- The eighth stage is the continuous improvement.
- The ninth stage is the final evaluation.
- The tenth stage is the final report.

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1. The first step in the process of the scientific method is to make an observation or ask a question.
2. Next, a hypothesis is made, which is an educated guess about the outcome of the experiment.
3. The hypothesis is then tested by conducting an experiment.
4. The results of the experiment are then analyzed to see if they support the hypothesis.
5. If the results do support the hypothesis, then the hypothesis is accepted as a theory.
6. If the results do not support the hypothesis, then the hypothesis is rejected and a new one is made.
7. The scientific method is a process that allows scientists to test their ideas and theories.
8. It is a way of thinking that is based on evidence and logic.
9. The scientific method is used in many different fields of study, including biology, chemistry, and physics.
10. It is a way of thinking that is used by scientists to make discoveries and solve problems.

## LIST OF DRAWINGS.

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## THE GENERAL PROBLEM.

In general the developement will consist of a dam across the river which may also be made to act as a spillway by raising vertical gates, a shore dam or retaining section, a power house and ship locks. The problem which presents itself is to determine the amount of power which can be economically developed. To do this, we must resort to government data, whereby we may determine the maximum and minimum stream flow and the available head and base our calculations accordingly.

The ship locks must be made according to government specifications, and as time does not permit we will not attempt to do anything with this branch of the project.

## LOCATION OF SITE.

The proposed development is situated on the Mississippi River about seven miles north of Rock Island, Illinois, and six miles north of Davenport, Iowa, the distances being measured along the river. Part of the electric power developed is intended to be used for manufactur-

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ing purposes in these towns and part is to be transmitted by high voltage to neighboring towns.

The advantages for construction and other purposes are excellent. The C.R.I. & P. R.R. and the C.M. & ST. P. R.R. run within a short distance of the site, and the C.R.I. & N.W. R.R. runs along the river bank. These railroads afford convenient means of communication with Moline and Rock Island and present ample means for transportation purposes. The river itself also presents excellent and cheap means for transporting construction materials.

#### SOURCE OF POWER AND STREAM MEASUREMENTS.

The source of power for this development lies in the fall of the river between Le Claire, Iowa, which is at the head of the rapids, and Rock Island Bridge at the foot of the rapids. From the head of the rapids to the site of the proposed dam the low water fall is 10.77 feet and the high water fall 8.67 feet. The low water elevation was assumed to be raised to Elev.

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100. 101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150. 151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200. 201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 222. 223. 224. 225. 226. 227. 228. 229. 230. 231. 232. 233. 234. 235. 236. 237. 238. 239. 240. 241. 242. 243. 244. 245. 246. 247. 248. 249. 250. 251. 252. 253. 254. 255. 256. 257. 258. 259. 260. 261. 262. 263. 264. 265. 266. 267. 268. 269. 270. 271. 272. 273. 274. 275. 276. 277. 278. 279. 280. 281. 282. 283. 284. 285. 286. 287. 288. 289. 290. 291. 292. 293. 294. 295. 296. 297. 298. 299. 300. 301. 302. 303. 304. 305. 306. 307. 308. 309. 310. 311. 312. 313. 314. 315. 316. 317. 318. 319. 320. 321. 322. 323. 324. 325. 326. 327. 328. 329. 330. 331. 332. 333. 334. 335. 336. 337. 338. 339. 340. 341. 342. 343. 344. 345. 346. 347. 348. 349. 350. 351. 352. 353. 354. 355. 356. 357. 358. 359. 360. 361. 362. 363. 364. 365. 366. 367. 368. 369. 370. 371. 372. 373. 374. 375. 376. 377. 378. 379. 380. 381. 382. 383. 384. 385. 386. 387. 388. 389. 390. 391. 392. 393. 394. 395. 396. 397. 398. 399. 400. 401. 402. 403. 404. 405. 406. 407. 408. 409. 410. 411. 412. 413. 414. 415. 416. 417. 418. 419. 420. 421. 422. 423. 424. 425. 426. 427. 428. 429. 430. 431. 432. 433. 434. 435. 436. 437. 438. 439. 440. 441. 442. 443. 444. 445. 446. 447. 448. 449. 450. 451. 452. 453. 454. 455. 456. 457. 458. 459. 460. 461. 462. 463. 464. 465. 466. 467. 468. 469. 470. 471. 472. 473. 474. 475. 476. 477. 478. 479. 480. 481. 482. 483. 484. 485. 486. 487. 488. 489. 490. 491. 492. 493. 494. 495. 496. 497. 498. 499. 500. 501. 502. 503. 504. 505. 506. 507. 508. 509. 510. 511. 512. 513. 514. 515. 516. 517. 518. 519. 520. 521. 522. 523. 524. 525. 526. 527. 528. 529. 530. 531. 532. 533. 534. 535. 536. 537. 538. 539. 540. 541. 542. 543. 544. 545. 546. 547. 548. 549. 550. 551. 552. 553. 554. 555. 556. 557. 558. 559. 560. 561. 562. 563. 564. 565. 566. 567. 568. 569. 570. 571. 572. 573. 574. 575. 576. 577. 578. 579. 580. 581. 582. 583. 584. 585. 586. 587. 588. 589. 590. 591. 592. 593. 594. 595. 596. 597. 598. 599. 600. 601. 602. 603. 604. 605. 606. 607. 608. 609. 610. 611. 612. 613. 614. 615. 616. 617. 618. 619. 620. 621. 622. 623. 624. 625. 626. 627. 628. 629. 630. 631. 632. 633. 634. 635. 636. 637. 638. 639. 640. 641. 642. 643. 644. 645. 646. 647. 648. 649. 650. 651. 652. 653. 654. 655. 656. 657. 658. 659. 660. 661. 662. 663. 664. 665. 666. 667. 668. 669. 670. 671. 672. 673. 674. 675. 676. 677. 678. 679. 680. 681. 682. 683. 684. 685. 686. 687. 688. 689. 690. 691. 692. 693. 694. 695. 696. 697. 698. 699. 700. 701. 702. 703. 704. 705. 706. 707. 708. 709. 710. 711. 712. 713. 714. 715. 716. 717. 718. 719. 720. 721. 722. 723. 724. 725. 726. 727. 728. 729. 730. 731. 732. 733. 734. 735. 736. 737. 738. 739. 740. 741. 742. 743. 744. 745. 746. 747. 748. 749. 750. 751. 752. 753. 754. 755. 756. 757. 758. 759. 760. 761. 762. 763. 764. 765. 766. 767. 768. 769. 770. 771. 772. 773. 774. 775. 776. 777. 778. 779. 780. 781. 782. 783. 784. 785. 786. 787. 788. 789. 790. 791. 792. 793. 794. 795. 796. 797. 798. 799. 800. 801. 802. 803. 804. 805. 806. 807. 808. 809. 810. 811. 812. 813. 814. 815. 816. 817. 818. 819. 820. 821. 822. 823. 824. 825. 826. 827. 828. 829. 830. 831. 832. 833. 834. 835. 836. 837. 838. 839. 840. 84

576.144 by building the dam thus giving a head of sixteen feet.

The period of lowest flow which occurred in 1864 shows that the discharge of the river at this point was 17,000 cubic feet per second, and the maximum discharge recorded is 250,000. second feet.

Government readings of the daily gage height at Rock Island, Illinois, for forty years are available, from which the stream flow could be calculated for every day. These gage readings, however, are too costly for our purpose, and it was decided to obtain only the readings for the lowest water year which are given on pages

A profile of the river at Rock Island was not available, so a cross-section of the river further up, giving approximately the same area and wetted perimeter, was used. Assuming that the velocity and discharge in this section were the same as those at Rock Island for minimum and maximum discharges, the water surface was given the same gage reading as those taken at Rock Is-



land. Other values for discharge were calculated by interpolation. From the above data we were able to plot a rating curve for the river at Rock Island where the zero of the gage reading, i.e. the lowest flow, corresponded to a discharge of 20,000 cubic feet per second. By changing the horizontal scale so as to read 17,000. instead of 20,000 the rating curve at the proposed site was obtained.

With the aid of the rating curve and the gage reading shown on pages 7-9 we were able to plot a hydrograph for the lowest water year at Rock Island. Then changing the vertical scales so as to read 17,000 instead of 20,000, a hydrograph of the river at the proposed site was obtained.

#### BACK WATER CALCULATIONS.

Assuming the river to be at the low water stage, the calculations for "C" in the formula:

$$C = \left( \frac{L}{Rh^{3/2}} \right)$$

were made in which the letters have the meaning as given below:

The first part of the paper is devoted to the study of the properties of the function  $f(x)$  defined by the equation  $f(x) = \int_0^x f(t) dt$ . It is shown that  $f(x)$  is a constant function, and its value is determined by the initial condition  $f(0) = 1$ . The second part of the paper is devoted to the study of the properties of the function  $g(x)$  defined by the equation  $g(x) = \int_0^x g(t) dt$ . It is shown that  $g(x)$  is a constant function, and its value is determined by the initial condition  $g(0) = 1$ .

The third part of the paper is devoted to the study of the properties of the function  $h(x)$  defined by the equation  $h(x) = \int_0^x h(t) dt$ . It is shown that  $h(x)$  is a constant function, and its value is determined by the initial condition  $h(0) = 1$ . The fourth part of the paper is devoted to the study of the properties of the function  $k(x)$  defined by the equation  $k(x) = \int_0^x k(t) dt$ . It is shown that  $k(x)$  is a constant function, and its value is determined by the initial condition  $k(0) = 1$ .

The fifth part of the paper is devoted to the study of the properties of the function  $l(x)$  defined by the equation  $l(x) = \int_0^x l(t) dt$ . It is shown that  $l(x)$  is a constant function, and its value is determined by the initial condition  $l(0) = 1$ . The sixth part of the paper is devoted to the study of the properties of the function  $m(x)$  defined by the equation  $m(x) = \int_0^x m(t) dt$ . It is shown that  $m(x)$  is a constant function, and its value is determined by the initial condition  $m(0) = 1$ .

$$f(x) = \int_0^x f(t) dt$$

The seventh part of the paper is devoted to the study of the properties of the function  $n(x)$  defined by the equation  $n(x) = \int_0^x n(t) dt$ . It is shown that  $n(x)$  is a constant function, and its value is determined by the initial condition  $n(0) = 1$ . The eighth part of the paper is devoted to the study of the properties of the function  $o(x)$  defined by the equation  $o(x) = \int_0^x o(t) dt$ . It is shown that  $o(x)$  is a constant function, and its value is determined by the initial condition  $o(0) = 1$ .

C = Coefficient depending on roughness of the channel.

V = Velocity at the section considered.

L = Length in feet between two sections.

h = Difference in elevation between two sections.

With 17,000 cubic feet flowing in the river, the coefficient "C" was determined for sixteen sections of the river. The average value of "C" thus determined was 50.

With the dam constructed and the elevation of the water surface raised to elevation 576.34 feet, the height of the water surface at Le Claire was determined, the discharge being taken as 250,000 cubic feet per second. The elevation of the water surface at Le Claire was found to be 587.098 feet.

Le Claire would not be affected by the building of the dam, but Rapids City across the river would be flooded to a height of 3.198 feet above the high water mark. This matter could be taken care of by either building a small retaining wall or by compensating the riparian owners who sustain any damages.



| GAGE READINGS AT ROCK ISLAND BRIDGE 1891. |      |      |      |      |      |      |      |      |       |      |      |      |
|---|------|------|------|------|------|------|------|------|-------|------|------|------|
| DATE                                      | JAN. | FEB. | MAR. | APR. | MAY  | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. |
| 1.  | 1.0  | 1.0  | 3.4  | 6.9  | 10.1 | 3.15 | 3.0  | 1.3  | 0.5   | 0.05 | 1.0  | 1.6  |
| 2.  | 0.9  | 1.45 | 3.4  | 7.35 | 10.2 | 3.1  | 2.95 | 1.2  | 0.55  | 0.00 | 0.95 | 1.4  |
| 3.  | 1.5  | 2.3  | 3.3  | 7.6  | 10.3 | 3.0  | 2.9  | 1.2  | 0.6   | 0.05 | 0.85 | 0.7  |
| 4.  | 1.5  | 3.9  | 3.6  | 7.65 | 10.3 | 3.1  | 3.1  | 1.15 | 0.55  | 0.2  | 0.8  | 0.3  |
| 5.  | 1.35 | 5.6  | 3.3  | 7.65 | 10.3 | 3.15 | 3.2  | 1.2  | 0.5   | 0.2  | 0.8  | 0.1  |
| 6.  | 1.2  | 6.1  | 3.1  | 7.65 | 10.2 | 3.4  | 2.95 | 1.2  | 0.5   | 0.25 | 0.8  | 0.3  |
| 7.  | 1.1  | 5.55 | 2.8  | 7.75 | 10.0 | 3.4  | 3.1  | 1.1  | 0.45  | 0.35 | 0.7  | 0.25 |
| 8.  | 1.2  | 5.45 | 2.9  | 7.85 | 9.7  | 3.2  | 3.25 | 1.0  | 0.45  | 0.45 | 0.8  | 1.7  |
| 9.  | 1.3  | 4.9  | 2.6  | 7.9  | 9.5  | 3.1  | 3.4  | 1.0  | 0.4   | 0.6  | 0.85 | 2.3  |
| 10.                                       | 1.4  | 5.5  | 2.3  | 8.1  | 9.05 | 3.0  | 3.4  | 0.9  | 0.4   | 0.7  | 0.9  | 1.9  |
| 11.                                       | 1.2  | 7.0  | 2.1  | 8.35 | 8.7  | 2.85 | 3.2  | 0.9  | 9.35  | 0.75 | 0.9  | 1.65 |

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| GAGE READINGS (Continued) |     |     |      |      |      |      |      |      |      |      |       |      |
|---------------------------|-----|-----|------|------|------|------|------|------|------|------|-------|------|
| 12.                       | 1.3 | 6.4 | 2.1  | 8.5  | 8.2  | 2.70 | 3.1  | 0.95 | 0.4  | 0.75 | 0.9   | 1.60 |
| 13.                       | 1.7 | 5.5 | 1.8  | 8.65 | 7.7  | 2.60 | 2.9  | 0.95 | 0.4  | 0.75 | 0.75  | 1.75 |
| 14.                       | 1.6 | 4.9 | 3.0  | 8.75 | 7.1  | 2.5  | 2.9  | 1.05 | 0.4  | 0.9  | 0.7   | 1.6  |
| 15.                       | 1.3 | 4.2 | 2.7  | 8.75 | 6.55 | 2.4  | 2.8  | 1.0  | 0.35 | 1.1  | 0.6   | 1.4  |
| 16.                       | 1.0 | 2.7 | 1.9  | 8.75 | 6.1  | 2.35 | 2.5  | 0.95 | 0.35 | 1.2  | 0.7   | 1.75 |
| 17.                       | 1.2 | 2.4 | 1.75 | 8.85 | 5.6  | 2.3  | 2.35 | 0.85 | 0.35 | 1.2  | 0.9   | 1.9  |
| 18.                       | 1.0 | 3.1 | 2.4  | 8.90 | 5.3  | 2.5  | 2.25 | 0.7  | 0.35 | 1.3  | 0.9   | 2.0  |
| 19.                       | 1.0 | 4.4 | 3.1  | 8.95 | 4.9  | 2.5  | 2.15 | 0.75 | 0.3  | 1.3  | 1.0   | 1.85 |
| 20.                       | 0.9 | 6.0 | 4.1  | 8.9  | 4.5  | 2.5  | 2.05 | 0.7  | 0.25 | 1.25 | -0.4  | 1.7  |
| 21.                       | 0.8 | 4.5 | 4.4  | 9.1  | 4.4  | 2.6  | 1.95 | 0.7  | 0.25 | 1.20 | -0.15 | 1.6  |
| 22.                       | 0.7 | 4.6 | 4.4  | 9.2  | 4.35 | 2.6  | 1.90 | 0.65 | 0.2  | 1.2  | 0.6   | 1.7  |
| 23.                       | 0.5 | 5.0 | 4.6  | 9.25 | 4.2  | 2.7  | 1.8  | 0.6  | 0.15 | 1.1  | 0.85  | 2.1  |

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|      |      |      |      |      |      |      |      |      |      |     |     |     |
|------|------|------|------|------|------|------|------|------|------|-----|-----|-----|
| 10.1 | 4.0  | 27.0 | 4.0  | 20.0 | 1.2  | 07.2 | 2.0  | 5.8  | 1.3  | 4.0 | 7.1 | .31 |
| 27.1 | 27.0 | 27.0 | 4.0  | 20.0 | 0.2  | 08.2 | 7.7  | 20.0 | 4.1  | 6.5 | 7.1 | .1  |
| 4.1  | 4.0  | 4.0  | 4.0  | 20.1 | 0.3  | 8.8  | 1.7  | 27.3 | 0.2  | 9.4 | 8.1 | .41 |
| 4.1  | 4.0  | 1.1  | 0.0  | 0.1  | 0.2  | 4.2  | 22.0 | 27.0 | 7.3  | 2.4 | 7.1 | .21 |
| 27.1 | 7.0  | 3.1  | 20.0 | 00.0 | 0.2  | 20.2 | 1.0  | 27.0 | 0.1  | 7.3 | 0.1 | .41 |
| 4.1  | 4.0  | 2.1  | 27.0 | 22.0 | 22.2 | 0.1  | 4.7  | 20.0 | 77.1 | 4.2 | 3.1 | .71 |
| 4.1  | 4.0  | 2.1  | 27.0 | 7.0  | 22.2 | 7.2  | 7.2  | 00.0 | 4.1  | 1.2 | 0.1 | .71 |
| 20.1 | 0.1  | 2.1  | 2.0  | 27.0 | 3.1  | 0.2  | 0.4  | 20.8 | 1.2  | 4.4 | 0.1 | .01 |
| 7.1  | 4.0  | 22.1 | 22.0 | 7.0  | 20.2 | 7.2  | 2.4  | 0.0  | 1.4  | 0.0 | 0.0 | .02 |
| 4.1  | 20.0 | 22.1 | 22.0 | 7.0  | 20.1 | 3.2  | 2.4  | 1.0  | 4.4  | 0.4 | 7.0 | .13 |
| 4.1  | 4.0  | 2.1  | 2.0  | 20.0 | 00.1 | 8.1  | 22.4 | 3.4  | 4.4  | 0.4 | 7.0 | .02 |
| 1.1  | 20.0 | 0.1  | 21.0 | 0.1  | 0.1  | 7.1  | 2.4  | 20.0 | 0.1  | 0.0 | 7.0 | .71 |

| GAGE READINGS (Continued) |      |      |     |       |      |      |      |      |      |      |      |      |
|---------------------------|------|------|-----|-------|------|------|------|------|------|------|------|------|
| 24.                       | 0.95 | 3.5  | 7.0 | 9.25  | 4.2  | 2.7  | 1.75 | 0.55 | 0.15 | 1.05 | 0.7  | 2.75 |
| 25.                       | 0.9  | 3.2  | 7.1 | 9.35  | 4.1  | 2.6  | 1.7  | 0.55 | 0.1  | 1.1  | 0.6  | 3.5  |
| 26.                       | 0.7  | 3.55 | 6.9 | 9.35  | 4.0  | 2.7  | 1.6  | 0.5  | 0.1  | 1.1  | 0.45 | 3.3  |
| 27.                       | 0.5  | 3.4  | 6.4 | 9.65  | 3.8  | 2.75 | 1.5  | 0.5  | 0.1  | 1.1  | 0.2  | 2.1  |
| 28.                       | 0.45 | 3.7  | 5.8 | 9.9   | 3.6  | 2.9  | 1.4  | 0.5  | 0.1  | 1.05 | 0.2  | 1.55 |
| 29.                       | 0.7  |      | 5.5 | 9.95  | 3.5  | 3.0  | 2.3  | 0.5  | 0.15 | 1.05 | 0.65 | 1.55 |
| 30.                       | 0.6  |      | 5.4 | 10.05 | 3.4  | 3.0  | 1.25 | 0.5  | 0.1  | 1.05 | 2.00 | 1.60 |
| 31.                       | 1.0  |      | 6.1 |       | 3.75 |      | 1.3  | 0.5  |      | 1.05 |      |      |

| (b)(5) DPP, (b)(7)(F) |      |          |       |         |       |         |       |         |       |         |       |
|-----------------------|------|----------|-------|---------|-------|---------|-------|---------|-------|---------|-------|
| Case No.              | Year | Amount   | Rate  | Amount  | Rate  | Amount  | Rate  | Amount  | Rate  | Amount  | Rate  |
| 1                     | 1980 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 2                     | 1981 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 3                     | 1982 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 4                     | 1983 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 5                     | 1984 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 6                     | 1985 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 7                     | 1986 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 8                     | 1987 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 9                     | 1988 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 10                    | 1989 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 11                    | 1990 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 12                    | 1991 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 13                    | 1992 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 14                    | 1993 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 15                    | 1994 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 16                    | 1995 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 17                    | 1996 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 18                    | 1997 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 19                    | 1998 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 20                    | 1999 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 21                    | 2000 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 22                    | 2001 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 23                    | 2002 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 24                    | 2003 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 25                    | 2004 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 26                    | 2005 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 27                    | 2006 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 28                    | 2007 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 29                    | 2008 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 30                    | 2009 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |
| 31                    | 2010 | \$100.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% | \$10.00 | 10.0% |

The only available data on the discharge measurements of the Mississippi River at Rock Island are given on the following table:

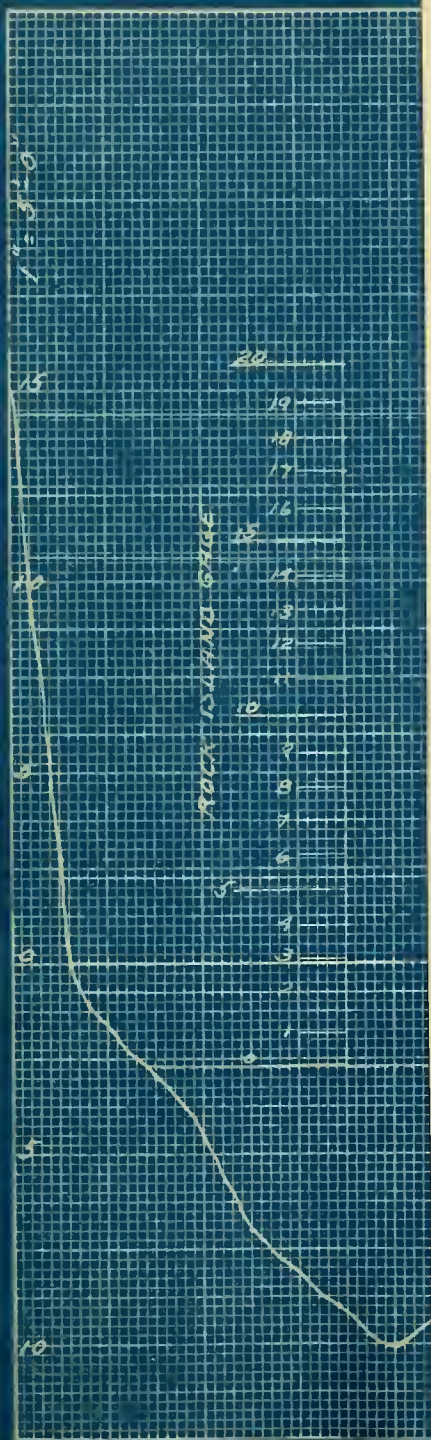
| Location    | Year. | Stage<br>above<br>L.W. | Width.<br>ft. | Wetted<br>per im-<br>iter.<br>ft. | Area<br>sq. ft. | Mean<br>velocity<br>per second<br>ft. | Discharge<br>per second<br>cu. ft. |
|-------------|-------|------------------------|---------------|-----------------------------------|-----------------|---------------------------------------|------------------------------------|
| Rock Island | 1878  | 2.1                    | 2,444         | 2,445                             | 19,109          | 1,5860                                | 30,313                             |
| do.         | 1880  | 18.4                   | 2,737         | 2,740                             | 60,880          | 4,3456                                | 251,348                            |

A cross-section of the river corresponding to the above data will be found on page .

-please establish and the above conditions  
 etc. In the case of the following conditions to be  
 added in the case of no new

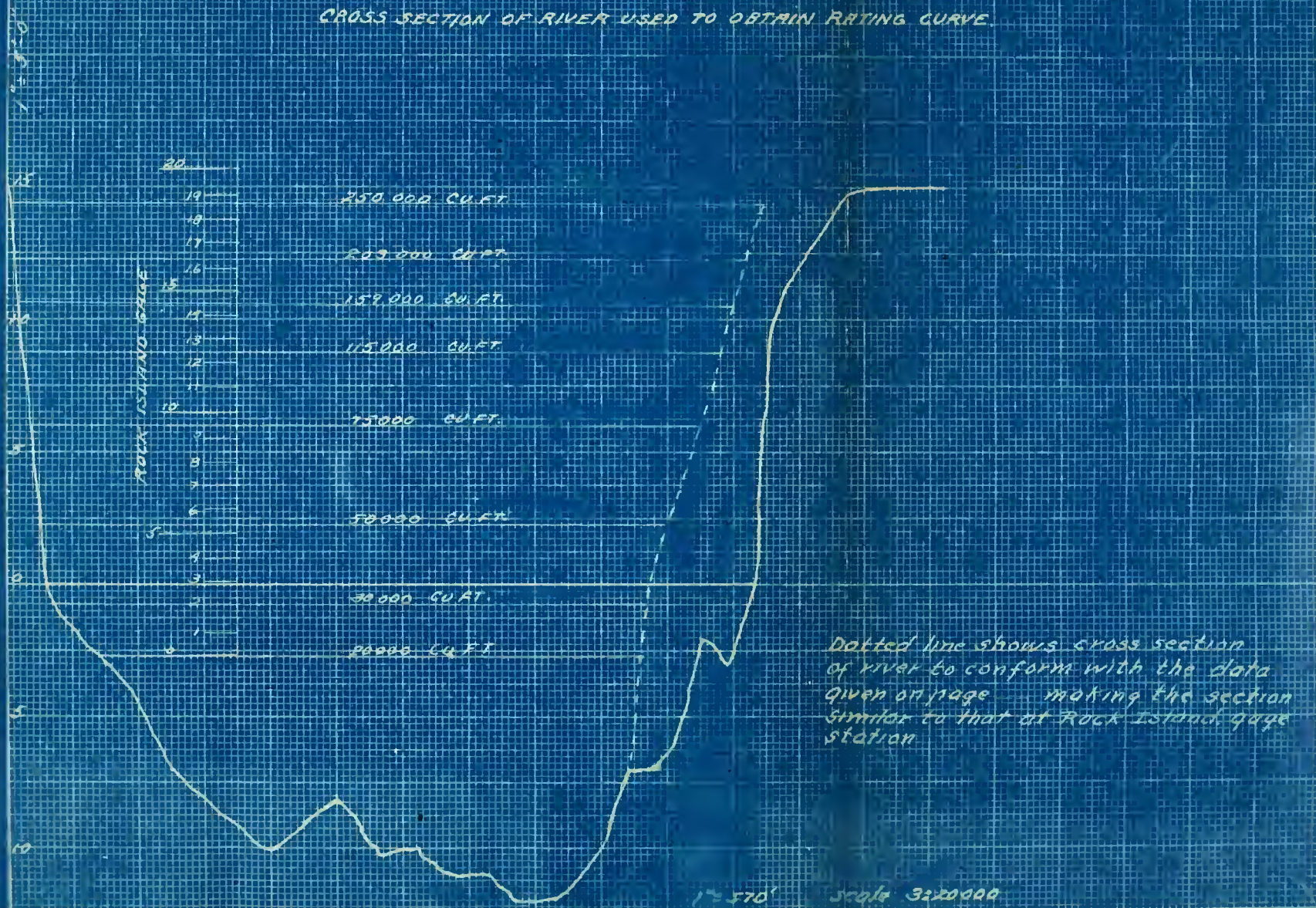
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-----|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |

1. The above conditions are to be added in the case of no new  
 2. The above conditions are to be added in the case of no new

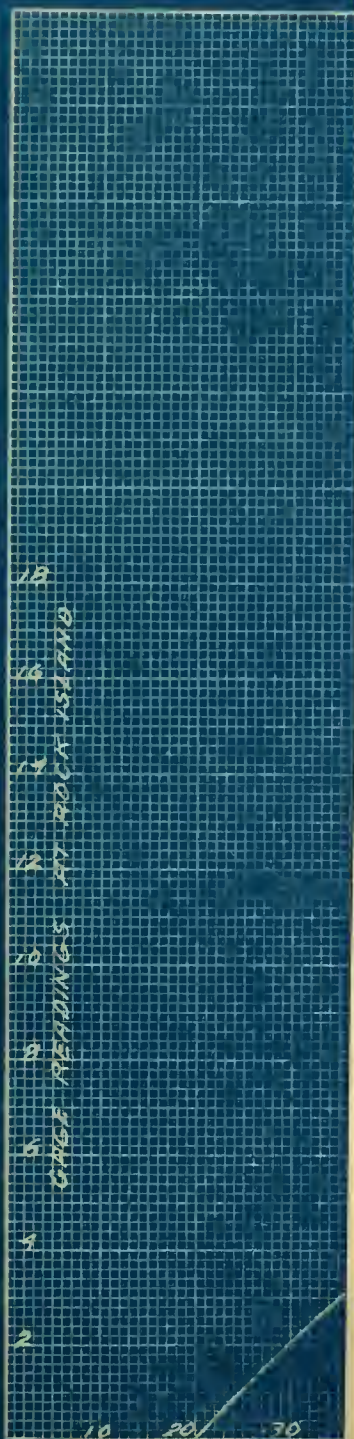




# CROSS SECTION OF RIVER USED TO OBTAIN RATING CURVE.









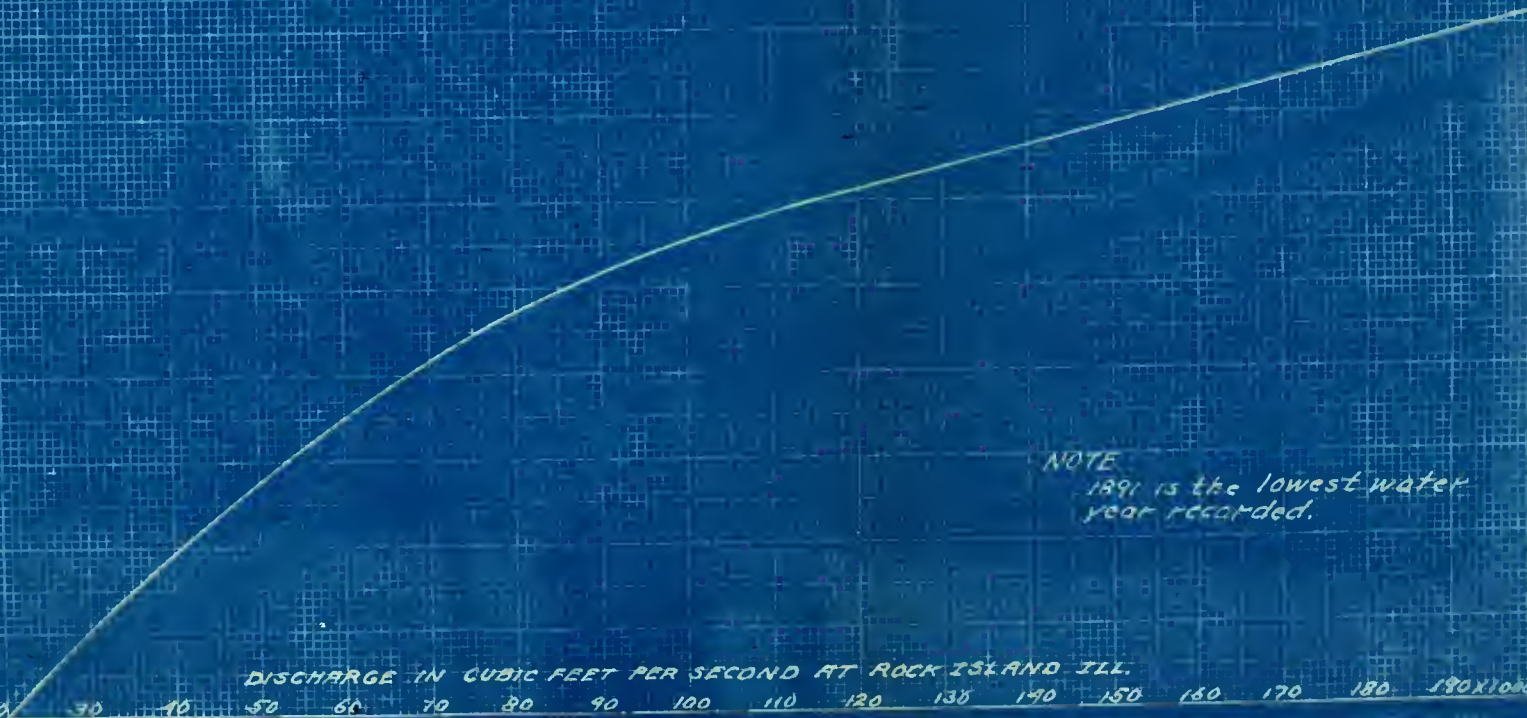
1891  
 RATING CURVE OF THE MISSISSIPPI RIVER  
 FROM OBSERVATIONS TAKEN AT ROCK ISLAND ILL.

18  
17  
16  
15  
14  
13  
12  
11  
10  
9  
8  
7  
6  
5  
4  
3  
2  
1  
0

NOTE  
 1891 is the lowest water  
 year recorded.

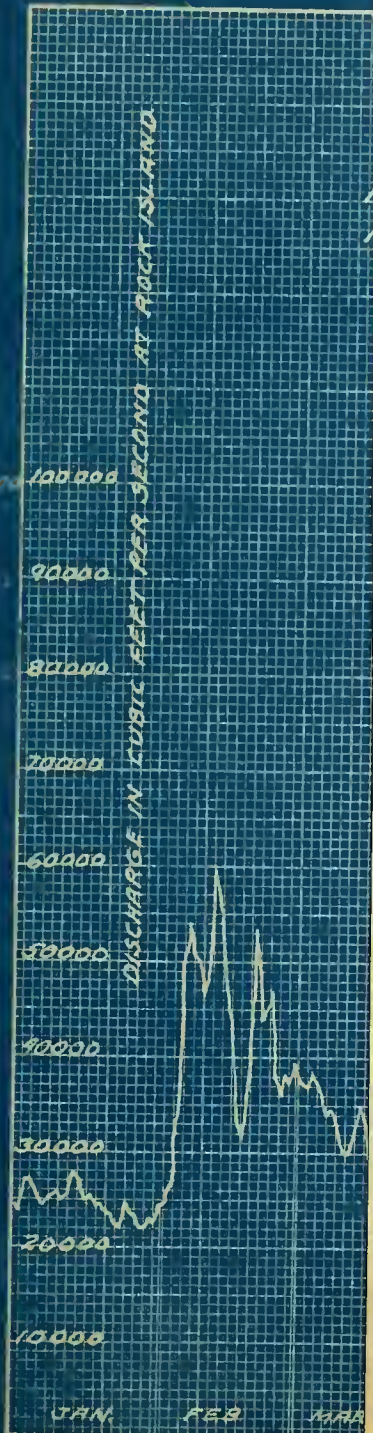
DISCHARGE IN CUBIC FEET PER SECOND AT ROCK ISLAND ILL.

10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200





A. Longitude

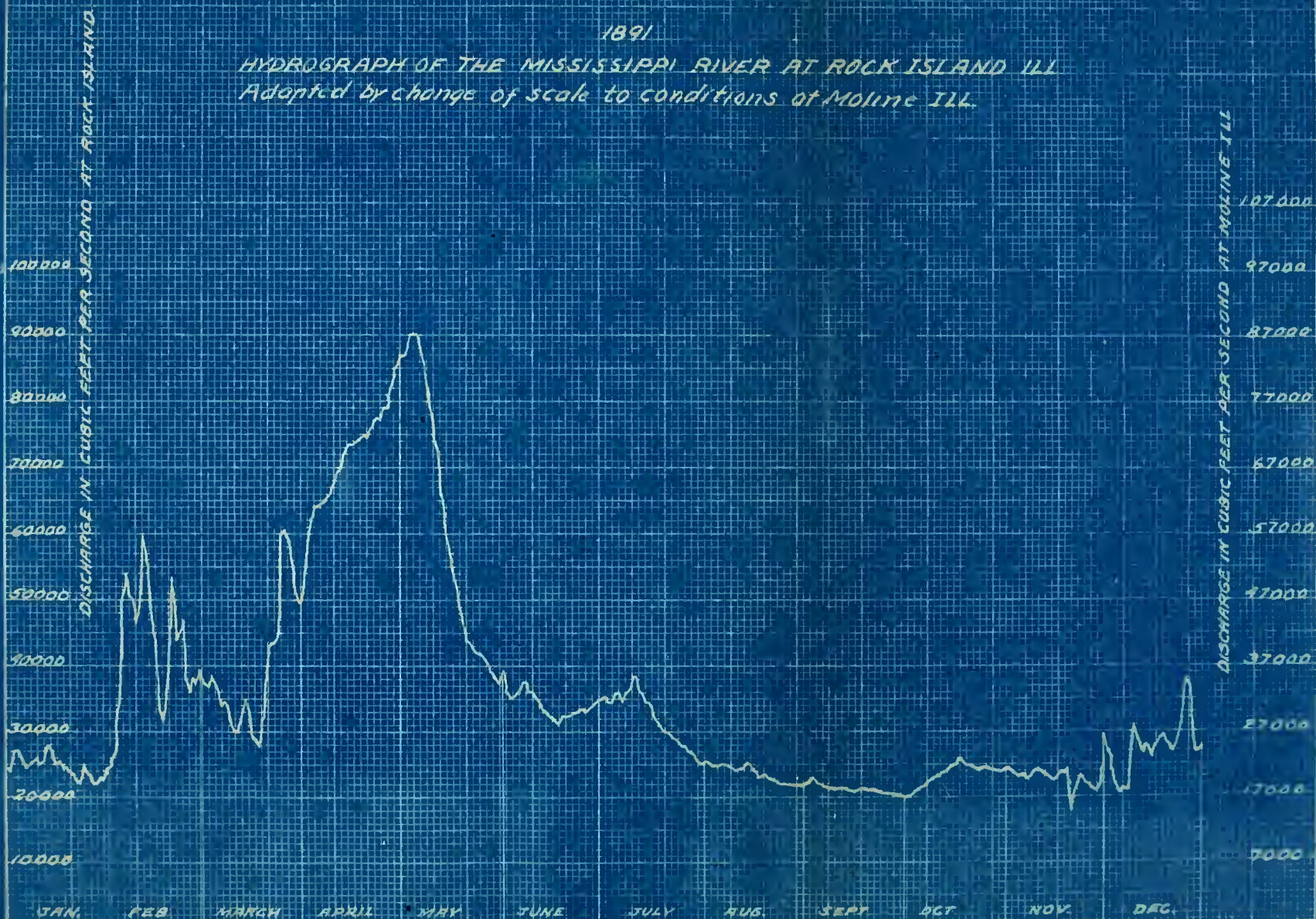




1891

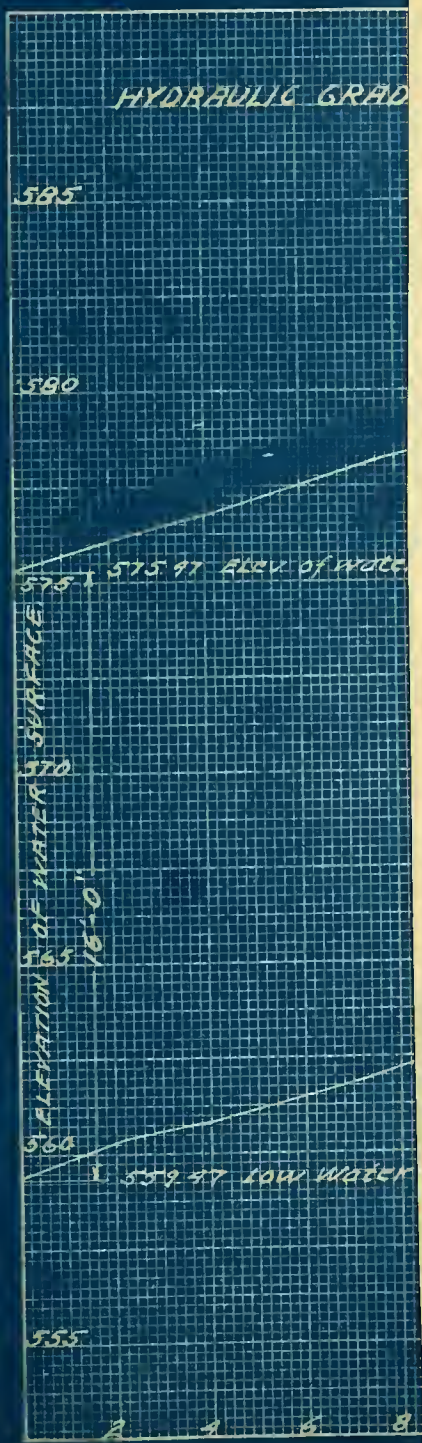
HYDROGRAPH OF THE MISSISSIPPI RIVER AT ROCK ISLAND ILL

Adapted by change of scale to conditions at Moline Ill.



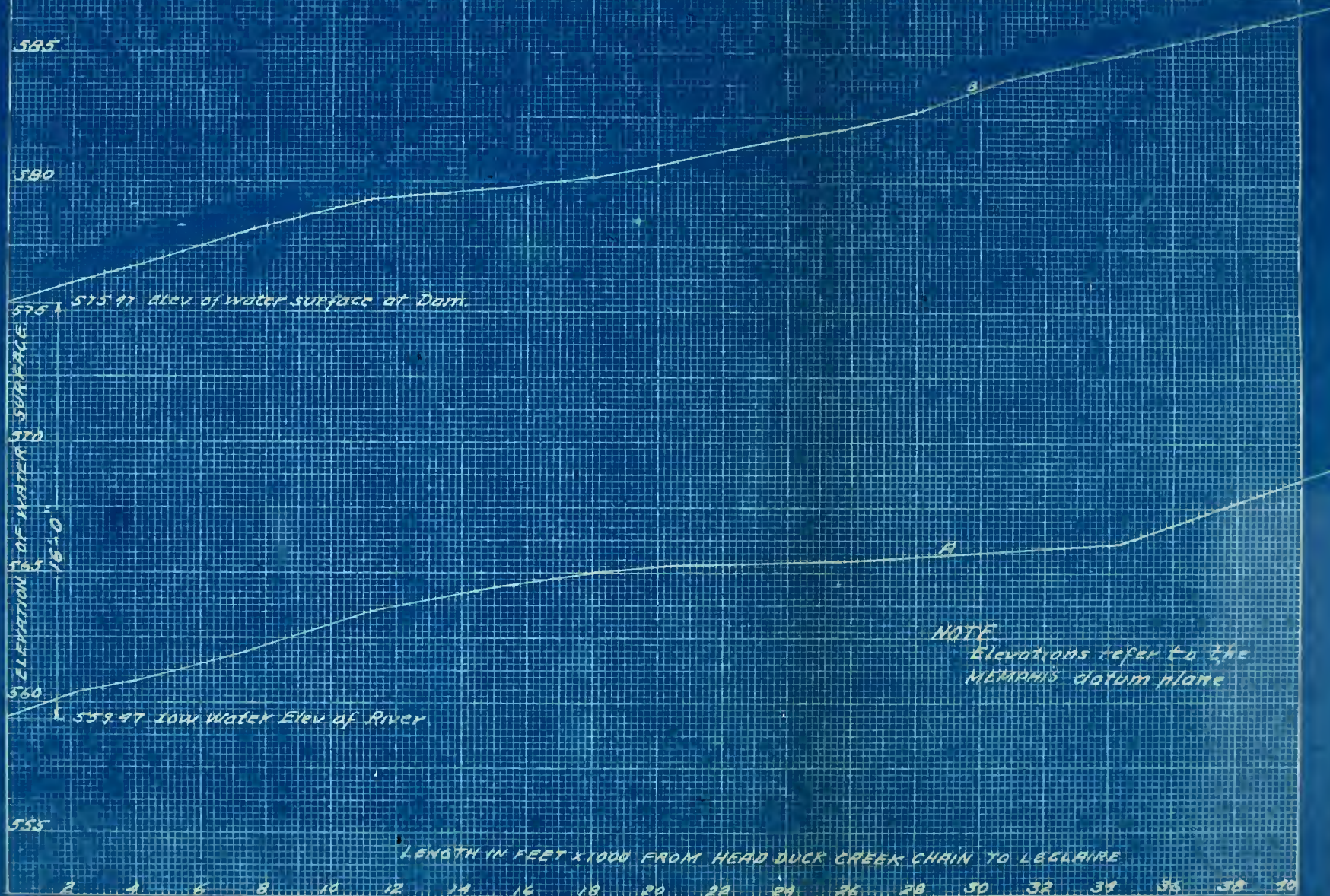


A. Longitude





# HYDRAULIC GRADE LINE OF THE MISSISSIPPI RIVER FROM MOLINE ILL TO LE CLAIRE IOWA





A longitudinal profile of the river showing the original and new water elevations caused by the dam is shown on page 17.

#### AVAILABLE POWER.

From a careful study of the hydrograph, it was thought inadvisable to base the calculations upon the minimum flow which only lasted thru a period of two days. A flow of 30,000 cubic feet per second may be relied upon for practically fifty per cent of the time, so this value was used with the assumption that a steam reserve could be depended upon during the dry periods.

The horse power available was calculated from the formula:

$$\text{H.P.} = \frac{qhEw}{550}$$

q = quantity of water in cu. ft. per sec.

h = head in feet.

E = Efficiency taken as 80%

w = weight of a cubic foot of water.

$$\text{H.P.} = \frac{30000 \times 16 \times .80 \times 62.5}{550} = 43,700 \text{ or}$$



say 45,000.

#### DESCRIPTION OF DAM.

The main dam from the Iowa side to the power house is designed to be 4625 feet long, of which 2975 feet is spillway in the present bed of the river and the remaining 1175 feet retaining shore dam. The spillway section of the dam is to consist of 119 arch spans, each twenty-five feet between piers four feet thick and an average height of thirty feet, forming a bridge eighteen feet wide on top. An Ogee shaped overfall will occupy the lower part of the space under each arch between the piers with a steel vertical lift gate resting on its crest to control the flow.

#### DESIGN OF DAM.

The maximum flood volume to be discharged is 280,000 cubic feet per second. Assuming that there will be 119 spillway sections, each section must discharge

$$\frac{280000}{119} = 2350 \text{ cubic feet per second.}$$

The length of the crest will be calculated from the formula:



$$L = \frac{Q}{C H^{\frac{3}{2}}}$$

Using a value of "C" equal to 3.33 and solving for L we get

$$L = \frac{2350}{3.33 \times 36.3} = 19.45 \text{ feet}$$

Because of the uncertainty in using the value of "C" it was deemed advisable to make L equal twenty-five feet. This will provide for a maximum discharge of

$Q = 3.33 \times 25 \times 36.3 \times 119 = 359,000$  cubic feet. of water per second or 28.2 per cent in excess of the required amount.

Diagrams showing the stresses in the dam with the reservoir empty and full are shown on drawings No. III. Stresses in the heel and toe were calculated from the formulas:

$$P = \frac{R \sin \alpha}{L} \left( 1 \pm \frac{6e}{L} \right)$$

R = Resultant pressure on base.

L = Length of base.

e = Eccentricity.

$\alpha$  = Angle that the resultant makes with the base.



### THE POWER HOUSE.

The power house which is located on the Illinois side, is 800 feet long, 109 feet wide and 123 feet high from the lowest point in the tail race to the highest point on the roof. It will contain twenty main turbine and generator units, and two smaller units.

The superstructure is built of reinforced concrete and contains three floors. The generators and transformers are located on the main floor. The second floor carries the oil-switches and the third the high tension bus-bars and the electrolytic lightning arresters.

The floors were designed as concrete slabs supported by steel I beams which rest either on concrete piers or are attached to pilasters. Triangle mesh reinforcement was used in the second and third floors.

The substructure is built almost entirely of concrete, steel being used only in two places, at the turbine bearing, and in the wall on the intake side of the power house.



### The Intakes and Scroll Cases:

The water enters each turbine thru three intakes which unite in forming the scroll case, the intakes being made with a gradually decreasing cross-section from the entrance to the scroll case. The scroll case is moulded in the concrete around the turbine, and its cross-section also decreases uniformly, the rate of decrease being such that the same amount of water, and at the same velocity, will pass thru equal parts of the turbine circumference.

### The Draft Tubes:

After passing thru the turbine the water enters the draft tube, which is circular and twelve feet in diameter immediately below the turbine. Each draft tube is forty feet long and in the first eight feet of its length the cross-section changes from a circular to an elliptical section then being maintained up to the tail race. The area keeps steadily increasing from the wheel to the tail race, the effect being to reduce the wheel discharge of 15.2 feet



per second to 4 feet per second at the end of the draft tube, and to increase the effective pressure of water on the turbines.

#### The Turbines:

There are twenty main turbines of the vertical shaft single runner type. Each turbine will develop 2500 H.P. under a sixteen foot head. The effective diameter of the turbine wheel is nine feet and it passes 1720 cubic feet of water per second under a sixteen foot head. Eighteen of the turbines are required to develop the rated output of the plant, two being kept as spare units and for use in times of high tail-water. The speed of the turbines is 56 r.p.m. To drive the excitors two small turbines are placed at the center of the power house. They are rated at 900 H.P. each, and under a sixteen foot head pass 573 cubic feet per second. All of the turbines are made by the Morgan Smith Co. To regulate the speed Lombard oil-pressure governors are used.

#### The Generators:

The generators are three phase, 25



cycle alternators, coupled directly to the turbines. They are built by the General Electric Co. and are of the revolving field type, having a rating of 1875 kva. at 11000 volts when operating at normal speed.

To excite the fields of the alternators and to furnish light to the station, two direct current, 500 KW. 110 volt generators are installed. If required, one of these machines is capable of supplying all of the excitation current needed by the alternators.

#### Other Electrical Apparatus.

The voltage of each alternator is stepped up from 11,000 to 70,000 volts by means of three single phase transformers. The transformers are each rated at 750 kva., and have both their primary and secondary sides connected in delta. The transformers are connected to the high-tension bus-bars thru 70,000 General Electric oil-switches, type H<sub>6</sub>. The low tension sides of the transformers are connected to the alternators thru General Electric K<sub>2</sub> switches.



To protect the transmission lines and the electrical apparatus from damage due to lightning discharge, electrolytic lightning arresters, connected to the lines thru horn gaps, are installed. The horn gaps are provided with disconnecting switches to disconnect the arrester from the line whenever it is required to do so.

#### Roof Trusses:

The steel roof trusses, which are spaced ten feet apart and span over the entire width of the building, were designed and built by the Chicago Bridge Co. They support the roof which is covered with green tiles.

#### Crane:

To provide for the handling of the generators and turbines, a thirty ton crane, placed forty-three feet above the generator floor, is used, the power required to operate it being taken from the direct current buses.



## DESIGN OF DAM.

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### Details of Design.

#### General Data:

The low water mark was taken at Elev. 560.34. By raising the water level sixteen feet at the dam the water surface will be at Elev. 576.34. The dam is so designed that the water surface will always be at the same level whether the river is discharging its maximum or minimum amount of water. Although the highest water level ever expected will only reach elevation 576.34, it was thought advisable to take 578.34 as a basis for the design. The top of the steel vertical lift-gates will be at Elev. 580.0.

These gates are to slide in vertical grooves in the concrete piers and are to be lifted and operated by a traveler of the wrecking-crane type, running on tracks upon the bridge.

#### Method of Design:

The dam will be designed in two separate sections as was done in the Keokuk project.

-----

1940

1940

- 1. The first part of the report is devoted to a general survey of the situation in the country.
- 2. The second part contains a detailed description of the economic situation.
- 3. The third part deals with the social and cultural life of the country.
- 4. The fourth part is devoted to the political situation.
- 5. The fifth part contains a summary of the main findings of the report.
- 6. The sixth part is a list of references.
- 7. The seventh part is a list of abbreviations.
- 8. The eighth part is a list of symbols.
- 9. The ninth part is a list of tables.
- 10. The tenth part is a list of figures.
- 11. The eleventh part is a list of maps.
- 12. The twelfth part is a list of appendices.
- 13. The thirteenth part is a list of footnotes.
- 14. The fourteenth part is a list of references.
- 15. The fifteenth part is a list of abbreviations.
- 16. The sixteenth part is a list of symbols.
- 17. The seventeenth part is a list of tables.
- 18. The eighteenth part is a list of figures.
- 19. The nineteenth part is a list of maps.
- 20. The twentieth part is a list of appendices.
- 21. The twenty-first part is a list of footnotes.
- 22. The twenty-second part is a list of references.
- 23. The twenty-third part is a list of abbreviations.
- 24. The twenty-fourth part is a list of symbols.
- 25. The twenty-fifth part is a list of tables.
- 26. The twenty-sixth part is a list of figures.
- 27. The twenty-seventh part is a list of maps.
- 28. The twenty-eighth part is a list of appendices.
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- 33. The thirty-third part is a list of tables.
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- 35. The thirty-fifth part is a list of maps.
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- 43. The forty-third part is a list of maps.
- 44. The forty-fourth part is a list of appendices.
- 45. The forty-fifth part is a list of footnotes.
- 46. The forty-sixth part is a list of references.
- 47. The forty-seventh part is a list of abbreviations.
- 48. The forty-eighth part is a list of symbols.
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- 50. The fiftieth part is a list of figures.
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- 52. The fifty-second part is a list of appendices.
- 53. The fifty-third part is a list of footnotes.
- 54. The fifty-fourth part is a list of references.
- 55. The fifty-fifth part is a list of abbreviations.
- 56. The fifty-sixth part is a list of symbols.
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- 58. The fifty-eighth part is a list of figures.
- 59. The fifty-ninth part is a list of maps.
- 60. The sixtieth part is a list of appendices.
- 61. The sixty-first part is a list of footnotes.
- 62. The sixty-second part is a list of references.
- 63. The sixty-third part is a list of abbreviations.
- 64. The sixty-fourth part is a list of symbols.
- 65. The sixty-fifth part is a list of tables.
- 66. The sixty-sixth part is a list of figures.
- 67. The sixty-seventh part is a list of maps.
- 68. The sixty-eighth part is a list of appendices.
- 69. The sixty-ninth part is a list of footnotes.
- 70. The seventieth part is a list of references.
- 71. The seventy-first part is a list of abbreviations.
- 72. The seventy-second part is a list of symbols.
- 73. The seventy-third part is a list of tables.
- 74. The seventy-fourth part is a list of figures.
- 75. The seventy-fifth part is a list of maps.
- 76. The seventy-sixth part is a list of appendices.
- 77. The seventy-seventh part is a list of footnotes.
- 78. The seventy-eighth part is a list of references.
- 79. The seventy-ninth part is a list of abbreviations.
- 80. The eightieth part is a list of symbols.
- 81. The eighty-first part is a list of tables.
- 82. The eighty-second part is a list of figures.
- 83. The eighty-third part is a list of maps.
- 84. The eighty-fourth part is a list of appendices.
- 85. The eighty-fifth part is a list of footnotes.
- 86. The eighty-sixth part is a list of references.
- 87. The eighty-seventh part is a list of abbreviations.
- 88. The eighty-eighth part is a list of symbols.
- 89. The eighty-ninth part is a list of tables.
- 90. The ninetieth part is a list of figures.
- 91. The ninety-first part is a list of maps.
- 92. The ninety-second part is a list of appendices.
- 93. The ninety-third part is a list of footnotes.
- 94. The ninety-fourth part is a list of references.
- 95. The ninety-fifth part is a list of abbreviations.
- 96. The ninety-sixth part is a list of symbols.
- 97. The ninety-seventh part is a list of tables.
- 98. The ninety-eighth part is a list of figures.
- 99. The ninety-ninth part is a list of maps.
- 100. The hundredth part is a list of appendices.

The pier will be assumed to take the dead load due to the weight of the arch bridge, the steel lift-gate when it is raised from the crest of the spillway, and the weight of the pier itself. It must also take any lateral pressure that the water may exert on the gates.

The overfall or spillway section, is so designed that the area of the base is sufficiently large to take care of the entire shearing force due to the lateral pressure of the water, without transmitting any of it to the piers.

The dam will be investigated when the pond is empty and when it is full for the following conditions:-

Maximum stresses at the toe and heel.

Stability against overturning.

Shearing force on the base.

Design of the Piers: Reservoir empty.

For the preliminary design the piers were assumed to be four feet thick. The top of the bridge was made 6.66 feet above the high water mark making the elevation 585.0 or 33.5

1. The first part of the paper is devoted to a general discussion of the problem of the existence of solutions of the system of equations (1) for arbitrary values of the parameters  $\alpha, \beta, \gamma, \delta, \epsilon, \zeta, \eta, \theta, \iota, \kappa, \lambda, \mu, \nu, \xi, \omicron, \pi, \rho, \sigma, \tau, \upsilon, \phi, \chi, \psi, \omega, \varphi, \eta, \theta, \iota, \kappa, \lambda, \mu, \nu, \xi, \omicron, \pi, \rho, \sigma, \tau, \upsilon, \phi, \chi, \psi, \omega, \varphi$ .

2. In the second part we shall consider the case when the parameters  $\alpha, \beta, \gamma, \delta, \epsilon, \zeta, \eta, \theta, \iota, \kappa, \lambda, \mu, \nu, \xi, \omicron, \pi, \rho, \sigma, \tau, \upsilon, \phi, \chi, \psi, \omega, \varphi$  are not arbitrary but satisfy certain conditions.

3. In the third part we shall consider the case when the parameters  $\alpha, \beta, \gamma, \delta, \epsilon, \zeta, \eta, \theta, \iota, \kappa, \lambda, \mu, \nu, \xi, \omicron, \pi, \rho, \sigma, \tau, \upsilon, \phi, \chi, \psi, \omega, \varphi$  are not arbitrary but satisfy certain conditions.

4. In the fourth part we shall consider the case when the parameters  $\alpha, \beta, \gamma, \delta, \epsilon, \zeta, \eta, \theta, \iota, \kappa, \lambda, \mu, \nu, \xi, \omicron, \pi, \rho, \sigma, \tau, \upsilon, \phi, \chi, \psi, \omega, \varphi$  are not arbitrary but satisfy certain conditions.

5. In the fifth part we shall consider the case when the parameters  $\alpha, \beta, \gamma, \delta, \epsilon, \zeta, \eta, \theta, \iota, \kappa, \lambda, \mu, \nu, \xi, \omicron, \pi, \rho, \sigma, \tau, \upsilon, \phi, \chi, \psi, \omega, \varphi$  are not arbitrary but satisfy certain conditions.

6. In the sixth part we shall consider the case when the parameters  $\alpha, \beta, \gamma, \delta, \epsilon, \zeta, \eta, \theta, \iota, \kappa, \lambda, \mu, \nu, \xi, \omicron, \pi, \rho, \sigma, \tau, \upsilon, \phi, \chi, \psi, \omega, \varphi$  are not arbitrary but satisfy certain conditions.

7. In the seventh part we shall consider the case when the parameters  $\alpha, \beta, \gamma, \delta, \epsilon, \zeta, \eta, \theta, \iota, \kappa, \lambda, \mu, \nu, \xi, \omicron, \pi, \rho, \sigma, \tau, \upsilon, \phi, \chi, \psi, \omega, \varphi$  are not arbitrary but satisfy certain conditions.

8. In the eighth part we shall consider the case when the parameters  $\alpha, \beta, \gamma, \delta, \epsilon, \zeta, \eta, \theta, \iota, \kappa, \lambda, \mu, \nu, \xi, \omicron, \pi, \rho, \sigma, \tau, \upsilon, \phi, \chi, \psi, \omega, \varphi$  are not arbitrary but satisfy certain conditions.

feet above the river bed. Assuming the concrete to weigh 150 pounds per cubic foot, the weight of the pier is:

$$\frac{18 + 36}{2} \times 33.5 \times 4 \times 150 = 542,000 \text{ lbs.}$$

and the weight of the bridge

$$\frac{2 + 4}{2} \times 18 \times 19 \times 150 = 10,600 \text{ lbs.}$$

making a total of 552,600 lbs.

By taking moments about the heel of the dam the resultant force was found to act at a distance of 13.9 feet from the heel, giving an eccentricity of 4.1 feet. Using the formula given on page 8 the maximum stress in the heel and toe were found to be:

$$P = \frac{552600}{36 \times 4} \left( 1 + \frac{6 \times 4.1}{36} \right) = 6512^{\#} \text{ per sq.ft.}$$

$$P = \frac{552600}{36 \times 4} \left( 1 - \frac{6 \times 4.1}{36} \right) = 2680^{\#} \text{ per sq.ft.}$$

Design of Pier:      Reservoir full.

The stresses in the abutment were next

The first part of the paper is devoted to the study of the properties of the function  $f(x)$  defined by the equation

$$f(x) = \frac{1}{2} \left( 1 + \frac{1}{x} \right) \quad (1)$$

which is satisfied by the function

$$f(x) = \frac{1}{2} \left( 1 + \frac{1}{x} \right) \quad (2)$$

In the second part of the paper we shall study the properties of the function  $f(x)$  defined by the equation

$$f(x) = \frac{1}{2} \left( 1 + \frac{1}{x} \right) \quad (3)$$

which is satisfied by the function

$$f(x) = \frac{1}{2} \left( 1 + \frac{1}{x} \right) \quad (4)$$

In the third part of the paper we shall study the properties of the function  $f(x)$  defined by the equation

$$f(x) = \frac{1}{2} \left( 1 + \frac{1}{x} \right) \quad (5)$$

which is satisfied by the function

$$f(x) = \frac{1}{2} \left( 1 + \frac{1}{x} \right) \quad (6)$$

$$f(x) = \frac{1}{2} \left( 1 + \frac{1}{x} \right) \quad (7)$$

$$f(x) = \frac{1}{2} \left( 1 + \frac{1}{x} \right) \quad (8)$$

The fourth part of the paper is devoted to the study of the properties of the function  $f(x)$  defined by the equation

$$f(x) = \frac{1}{2} \left( 1 + \frac{1}{x} \right) \quad (9)$$

which is satisfied by the function

$$f(x) = \frac{1}{2} \left( 1 + \frac{1}{x} \right) \quad (10)$$

calculated by assuming the level of the water in the pond to be at Elev. 578.34 and with the lift-gate resting on the crest of the spillway.

As before, the total dead load will be 552,600 lbs. acting at a distance of 13.9 feet from the heel of the dam.

The horizontal pressure on the gate due to the water was found to be:

$$\frac{687.5}{2} \times 11 \times 25 = 94,500 \text{ \#}$$

By combining these two forces graphically, the resultant pressure was found to be 560,000 lbs. with an eccentricity of three inches. The eccentricity in this case is so small that the pressure may be considered as being uniformly distributed over the base, making the pressure per square foot equal to

$$\frac{552,600}{36 \times 4} = 3870 \text{ \#}$$

#### Safety Against Overturning:

The only force tending to overturn the

The first part of the paper is devoted to the study of the properties of the function  $f(x)$  defined by the equation  $f(x) = \frac{1}{x} \int_0^x f(t) dt$ . It is shown that  $f(x)$  is a constant function. The second part of the paper is devoted to the study of the properties of the function  $g(x)$  defined by the equation  $g(x) = \frac{1}{x} \int_0^x g(t) dt$ . It is shown that  $g(x)$  is a constant function. The third part of the paper is devoted to the study of the properties of the function  $h(x)$  defined by the equation  $h(x) = \frac{1}{x} \int_0^x h(t) dt$ . It is shown that  $h(x)$  is a constant function.

$$f(x) = \frac{1}{x} \int_0^x f(t) dt$$

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$$f(x) = \frac{1}{x} \int_0^x f(t) dt$$

The first part of the paper is devoted to the study of the properties of the function  $f(x)$  defined by the equation  $f(x) = \frac{1}{x} \int_0^x f(t) dt$ . It is shown that  $f(x)$  is a constant function.

dam will be the horizontal water pressure, and the force tending to hold it down is the weight of the part considered. These two forces acting at right angles to each other form couples upon which the stability of the structure is dependent.

The dam will tend to overturn about the toe, which is therefore taken as the center of moments. The overturning force is

$$94,500 \times 19 = 179,600 \text{ Ft. Lbs.}$$

The resisting force is

$$552,680 \times 22.1 = 12,180,00 \text{ Ft. Lbs.}$$

Factor of safety against overturning

$$\frac{12,180,000}{179,600} = 67.8$$

Shearing on the Base:

To prevent the dam from moving bodily down stream the entire base was embedded four feet below the river bed which is of blue limestone and able to withstand a bearing pressure

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$$... = \frac{...}{...}$$

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of thirty tons per square foot.

The force tending to shear off the base is the horizontal water pressure. This shearing force is resisted by the area of the pier at the base. The unit shearing force is then:

$$\frac{94500}{36 \times 4 \times 144} = 4.56 \text{ \# per sq. in.}$$

#### Design of Spillway, Pond Empty:

In determining the shape of the overfall it was decided to make the spillway conform as nearly as possible to the shape of a parabola. The equation of the parabola selected was

$$y = \sqrt{10x}$$

This equation did not give quite the form desired, but by broadening out the curve a little the desired results were obtained.

For the preliminary design the width of the base was taken as 29 feet and the height above the river bed as 15.5 feet. Considering a section one foot wide, the weight is approximately 46,000 lbs. acting at a distance of ten

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$$\frac{1}{2} \left( \frac{1}{2} + \frac{1}{2} \right) = \frac{1}{2}$$

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RESEARCH REPORT

NO. 1000

feet from the heel of the dam. The steel gate was assumed to weigh 2000 lbs. making a total weight of 48,000 lbs.

With an eccentricity of 4.5 feet the pressure at the heel and toe were found to be

$$P = \frac{48,000}{29} \left( 1 + \frac{6 \times 4.5}{29} \right) = 3200\# \text{ per sq.ft.}$$

$$P = \frac{48,000}{29} \left( 1 - \frac{6 \times 4.5}{29} \right) = 150\# \text{ per sq.ft.}$$

#### Design of Spillway, Pond Full:

The dead load will be the same as before, 48,000 lbs. In addition to this we have for the vertical weight 2000# additional, due to the water on the crest, thus making a total of 50,000 lbs.

The horizontal water pressure is

$$\frac{62.5(33.5 - 15.42) 15.42}{2} = 15,600\#$$

Combining the above forces graphically, the resultant pressure was found to be 52,000 # with an eccentricity of eleven inches,

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$$f(x) = \left( \frac{1}{x} + 1 \right) \frac{1}{x} = \frac{1}{x^2} + \frac{1}{x}$$

$$f'(x) = -\frac{2}{x^3} + \frac{1}{x^2}$$

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$$f(x) = \frac{1}{x} \ln(x)$$

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thus making the pressure at the heel and toe

$$P = \frac{50,000}{29} \left( 1 + \frac{6 \times .833}{29} \right) = 3000\# \text{ per sq.ft.}$$

$$P = \frac{50,000}{29} \left( 1 - \frac{6 \times .833}{29} \right) = 1452\# \text{ per sq.ft.}$$

Shear on Base:

The area to resist the shear is  $29 \times 1 = 29$  sq. ft. making the shear per sq. in.

$$\frac{15600}{29 \times 144} = 3.73 \#$$

Stability :

The overturning moment is

$$15,600 \times 10.6 = 165,500 \text{ Ft. Lbs.}$$

Resisting Moment:

$$50,000 \times 19 = 950,000 \text{ Ft. Lbs.}$$

Factor of Safety:

$$\frac{950,000}{165,500} = 5.26$$

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## THE POWER HOUSE.

===

### Detail Design.

#### Gallery Floor:

The gallery floor is designed to carry the lightning arresters, the high tension bus-bar compartments and the line compartments.

I beams support this floor every four feet in order to carry the load on this floor to the wall and to the posts. This floor, and the two floors below it, are 28 ft. 6 in. wide. The weight of each lightning arrester is 2750#, of the bus bar compartment 5912# and of the line compartment 10,800#.

These loads give a maximum bending moment of 662,400 in. lbs., and for a working stress of 16,000 lbs. per sq. in. in the steel I beam whose section modulus is

$$\frac{662,400}{16,000} = 42, \text{ needed.}$$

12 in. 40 lb. I beams have the requir-

1. 1910 [1910]

1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

ed section modulus and are used. They carry the 3.5 in floor slab on which the compartments and lightning arresters are placed.

As there is no wall to fasten these I beams to on the side nearest the generator room, they are fastened to other I beams, 20 ft. in length running lengthwise of the building between steel posts. The posts are 20 ft. apart and the I beams between them must support the load of four of the 12 in. 40 lbs. I beams.

The section modulus found for the 20 ft. I beams was 207, which gave 24"-105# I beams for the girders between posts.

#### Balcony Floor :

This floor is designed to carry the weight of the oil switches and line compartments. A concrete slab 4.5" thick was used, and I beams were placed under it every 4 feet, as in the floor above.

The weight from the oil switch which goes to one I beam was 11,340#, and the weight of the compartment 9180#. 18"-70# I beams are



needed for this floor between the wall and girders, the girders being 20"-85# I beams.

#### Transformer Floor:

On account of the depression in the floor for the tracks running along the building, the beams in the floor were not placed as in the other two floors, but lengthwise. This was done to avoid an excessive use of concrete for the floor slab.

The transformers weigh 12,935# each, and are placed 10 ft. apart. The area of the bottom of each transformer is 13.75 sq. ft., which gives 942.5 # per sq. ft. of floor. The bending moment due to this load is

$$\frac{1}{8} w l^2 = \frac{942.5 \times 3 \times 3 \times 12}{8} = 12,720 \text{ in.lbs.}$$

the beams which are to support the concrete slab being three feet apart.

The thickness of concrete required is

$$d = \sqrt{\frac{M}{R b}} = \frac{12720}{110 \times 12} = 9.65 \text{ in.}$$

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The slab was made 10" thick and weighs 120# per sq. Ft.

Each beam supports a three foot width of slab = 360 # per ft.

$$\text{B.M.} = \frac{1}{8} w l^2 = \frac{360 \times 20 \times 20 \times 12}{8} = 130,000 \text{ in.lbs.}$$

When the transformers are moved, each beam will have to take half the weight of one transformer, and this must be considered.

This gives a bending moment of 388,000 in. lbs. which must be added to the 130,000 previously found. The I beams required to resist the total bending moment are 12"-31.5#

These are supported every ten feet by beams af, de, bg, etc., each of which carries the load of one transformer in one panel as afde. The members required for this load are 24"-80# I beams.

The beams between the 20 ft. posts, as de, must be carried on girders ab, bc, etc., ab carries one half the load from de, and the beams required are 18"-65# I beams.

(1) The first part of the paper is devoted to the study of the

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### Design of Racks:

The size of openings in the racks was made so that velocity of the water thru the racks was about 1.5 ft. per second. This would make each opening

$$\frac{1720}{1.5} = 1150 \text{ sq. ft.}$$

1720 cubic feet per second being the discharge of each turbine.

The racks were made thirty feet wide and forty feet long, the vertical height being thirty-eight feet. They consist of narrow bars of iron  $\frac{1}{4}$ " x 3", spaced 2" apart resting on horizontal I beams spaced 5' apart, which in turn are supported by two heavy I beams at the sides of the opening. These two I beams, running parallel to the racks, must be designed to withstand the full head of water in case the racks should be choked up with leaves or other materials.

The total pressure which each beam would have to take is:



$$\frac{38}{2} \times 15 \times 40 \times 62.5 = 710,000 \text{ ft. lbs.}$$

This pressure acts at a distance of  $\frac{38}{2}$  feet from the bottom, but was taken as uniformly distributed in order to simplify the calculations:

$$M = \frac{Wl^2}{8} = \frac{710,000 \times 12}{8} = 1,065,000 \text{ in.lbs.}$$

$$\frac{I}{C} = \frac{1,065,000}{16,000} = 73, \text{ which corresponds}$$

to the section modulus of a 15"-60# I beam.

The clear opening thru the racks is

$$38 \times \frac{7}{8} \times 30 = 1000 \text{ sq. ft.}$$

which gives a velocity of 1.72 ft. per second thru the racks.

Let  $f(x)$  be a function of  $x$  and let  $g(x)$  be a function of  $x$ .

Then the function  $h(x)$  is defined by

$h(x) = f(x) + g(x)$  and the function  $k(x)$  is defined by

$k(x) = f(x) - g(x)$ .

Then

$$h'(x) = f'(x) + g'(x) \quad \text{and} \quad k'(x) = f'(x) - g'(x).$$

$$\text{Proof.} \quad h'(x) = \lim_{\Delta x \rightarrow 0} \frac{h(x+\Delta x) - h(x)}{\Delta x} = \lim_{\Delta x \rightarrow 0} \frac{f(x+\Delta x) + g(x+\Delta x) - f(x) - g(x)}{\Delta x} = \lim_{\Delta x \rightarrow 0} \frac{f(x+\Delta x) - f(x)}{\Delta x} + \lim_{\Delta x \rightarrow 0} \frac{g(x+\Delta x) - g(x)}{\Delta x} = f'(x) + g'(x).$$

Similarly,  $k'(x) = f'(x) - g'(x)$ .

Q.E.D.

$$\text{Corollary.} \quad \text{If } f(x) = c \text{ and } g(x) = c, \text{ then } h(x) = 2c \text{ and } k(x) = 0.$$

Proof.  $h(x) = f(x) + g(x) = c + c = 2c$  and  $k(x) = f(x) - g(x) = c - c = 0$ .

Q.E.D.

# GENERAL ESTIMATE OF COST.

The figures as given below are only approximate and were obtained by comparison with the costs of existing plants and other installations of which the actual costs were known.

The Electrical World of 1910 gives the cost of the generators as \$11.00 per Horse Power generated. Since the turbines deliver 450,000 Horse Power at the turbine shaft the cost of the generators will be

$$450,000 \times \$11.00 = \$495,000.$$

Gillette's hand book of cost data gives the cost of an 800 KW. step-up transformer as \$7500. Taking this as a basis, the cost per KW. would be

$$\frac{7500}{800} = \$9.48$$

Assuming that the generators have an efficiency of 95%, the total power to be transformed is:

THEORY OF THE EARTH

CHAPTER I. OF THE ORIGIN OF THE EARTH.

THE EARTH, AS WE SEE IT, IS A GLOBE, OR SPHERE, OF WHICH THE SURFACE IS COVERED BY WATER, AND THE INTERIOR BY A SOLID MATTER.

- The water which covers the surface of the globe is called the OCEAN, and is divided into SEAS, BAYS, GULFS, &c.
- The solid matter which forms the interior of the globe is called the EARTH, and is divided into MOUNTAINS, RIVERS, &c.

THE EARTH IS DIVIDED INTO TWO PARTS, THE NORTH AND SOUTH POLES.

THE NORTH POLE IS THAT PART OF THE EARTH WHICH IS NEAREST TO THE NORTH STAR, AND THE SOUTH POLE IS THAT PART WHICH IS NEAREST TO THE SOUTH STAR. THE LINE WHICH DIVIDES THE EARTH INTO THE NORTH AND SOUTH POLES IS CALLED THE EQUATOR, AND IS THE CENTER OF THE EARTH.

THE EARTH IS DIVIDED INTO FOUR PARTS, THE NORTH, SOUTH, EAST, AND WEST.

- The North part of the globe is called the NORTH POLE, and the South part is called the SOUTH POLE.
- The East part of the globe is called the EAST POLE, and the West part is called the WEST POLE.
- The line which divides the globe into the North and South poles is called the EQUATOR, and the line which divides the globe into the East and West poles is called the MERIDIAN.

$$EARTH = \frac{1}{2} \text{ of the globe}$$

THE EARTH IS DIVIDED INTO TWO PARTS, THE NORTH AND SOUTH POLES.

THE NORTH POLE IS THAT PART OF THE EARTH WHICH IS NEAREST TO THE NORTH STAR, AND THE SOUTH POLE IS THAT PART WHICH IS NEAREST TO THE SOUTH STAR.

$$450,000 \times .95 = 42,750 \text{ K.W.}$$

making the cost of the transformers,

$$42,750 \times 9.48 = \$406,000.$$

The cost of the exciter units was taken from data given by H.M. Hobart in the Standard Handbook, who gives the cost of a 1000 K.W. direct current generator as \$10,500.

The oil switches of which there are twenty for generators and six for the out-going lines, may be obtained from the General Electric Co. at a cost of \$1200. per switch, making the total cost

$$26 \times 1200. = \$33,200.$$

The lightning arresters may be also obtained from the same company at a cost of \$1400. There will be six of these making the cost

$$1400 \times 6 = \$8400.$$

Data for the cost of the dam and power house was taken from Gillette's Handbook of Cost Data, in which the cost of a similar dam was giv-

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en as \$5.92 per cu. yd. which includes the cost of labor, concrete and form work.

The dam project will contain 61,500 cubic yards, making the cost

$$61,500 \times \$5.92 = \$363,000.$$

The power house will contain 46,400 cubic yards, making the cost

$$46,400 \times \$5.92 = \$274,000.$$

There will be a total of 85 miles of transmission line at approximately \$5000. per mile making

$$5000 \times 85 = \$425,000.$$

Switch board and station wiring will cost  $9/40$  of the generator and transformer cost or

$$9/40 \times 911,000 = \$205,000.$$

The water wheels will have a cost of approximately  $36.65/40$  of the generator and transformers making

$$\frac{36.65}{40} \times 911000 = \$752,000.$$

Allowing 10% for engineers charges and

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 equation  $k(x) = \int_0^x \frac{1}{1+t^2} dt$  for  $x \in \mathbb{R}$ . It is shown  
 that  $k(x)$  is an even function and that  $k(x) \in C^1(\mathbb{R})$ .  
 The fifth part of the paper is devoted to the study of the  
 function  $l(x)$  defined by the equation  $l(x) = \int_0^x \frac{1}{1+t^2} dt$   
 for  $x \in \mathbb{R}$ . It is shown that  $l(x)$  is an odd function and  
 that  $l(x) \in C^1(\mathbb{R})$ . The sixth part of the paper is  
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 that  $o(x)$  is an even function and that  $o(x) \in C^1(\mathbb{R})$ .  
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 function  $p(x)$  defined by the equation  $p(x) = \int_0^x \frac{1}{1+t^2} dt$   
 for  $x \in \mathbb{R}$ . It is shown that  $p(x)$  is an odd function and  
 that  $p(x) \in C^1(\mathbb{R})$ . The tenth part of the paper is  
 devoted to the study of the function  $q(x)$  defined by the  
 equation  $q(x) = \int_0^x \frac{1}{1+t^2} dt$  for  $x \in \mathbb{R}$ . It is shown  
 that  $q(x)$  is an even function and that  $q(x) \in C^1(\mathbb{R})$ .

10% for contingency charges, the total cost would be approximately \$3,600,000.



## TRANSMISSION LINE.

=====

## Design of Peoria Line.

20,000 KW. are to be transmitted along this line to Peoria, Ill., a distance of seventy-five miles. Two circuits will be used, each of which will normally carry one half of the power. The voltage at the receiver is 65000 volts, which gives a voltage from line to neutral of 37,800 volts.

The assumed loss at full load, with all wires in use is 15%, which gives

$$\frac{20,000 \times 15}{600} = 500 \text{ KW. as the I R loss in one}$$

line.

The current per wire is :

$$\frac{10,000 \times 1000}{3 \times 65,000} = 89 \text{ amperes .}$$

The resistance per wire is :

$$\frac{500,000}{89 \times 89} = 62.4 \text{ ohms, or .16 ohms per 1000 ft.}$$

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#2 solid copper wire, having a resistance of #1594 ohms per 1000 ft. was used. This gives an actual loss of

$$89 \times 89 \times .1594 \times 5.28 \times 75 = 500,000 \text{ watts per line.}$$

The towers are placed 600 feet apart, and the distance between the wires, which are placed at the corners of triangles, is nine feet.

The inductance of each wire is:

$$.1404 \log \frac{\delta}{r} + .01524 \text{ millihenries} = .1404$$

$$\log \frac{9 \times 12}{.129} + .01524 = .425 \text{ millihenries}$$

per 1000 ft.

The capacity to neutral is:

$$\frac{38.8 \times 10}{\log \frac{2D}{d}} = \frac{38.8 \times 10}{\log \frac{18 \times 12}{.258}} = 13.3 \times 10 \text{ farads}$$

per mile.

The inductance per wire is:

$$.425 \times 75 \times 5.28 = .167 \text{ henries} = L$$

Let  $f(x)$  be a function defined on the interval  $[a, b]$ . Then the definite integral of  $f(x)$  from  $a$  to  $b$  is denoted by

$$\int_a^b f(x) dx$$

and is equal to the limit of the sum of the areas of the rectangles

under the curve  $y = f(x)$  as the number of rectangles increases indefinitely.

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and is equal to the limit of the sum of the areas of the rectangles

$$\int_a^b f(x) dx = \lim_{n \rightarrow \infty} \sum_{k=1}^n \frac{b-a}{n} f(x_k)$$

under the curve  $y = f(x)$  as the number of rectangles increases indefinitely.

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under the curve  $y = f(x)$  as the number of rectangles increases indefinitely.

The inductive reactance is:

$$2 fL = 2 \times 25 \times .167 = 26.5 \text{ ohms per wire.}$$

The condensive reactance is

$$\frac{1}{2\pi fc} = \frac{1}{2 \times 25 \times 13.3 \times 10^3 \times 75} = 6360 \text{ ohms.}$$

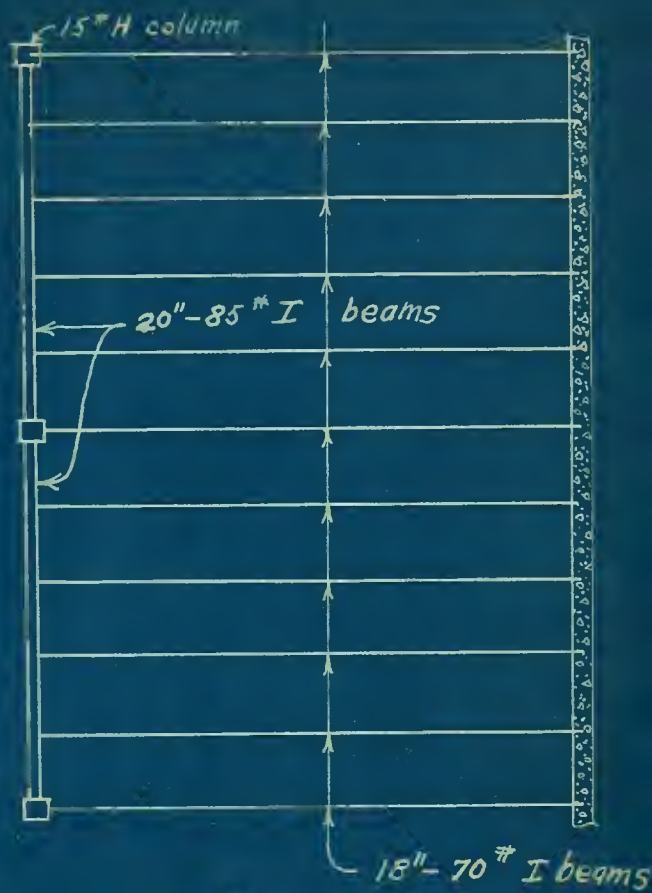
By constructing the regulation diagram the above values give 16 % for regulation at full non-inductive load and 15.8% for regulation for full load current 80% lagging power factor.



PLAN OF GALLERY FLOOR



PLAN OF BALCONY FLOOR



PLAN OF TRANSFORMER FLOOR



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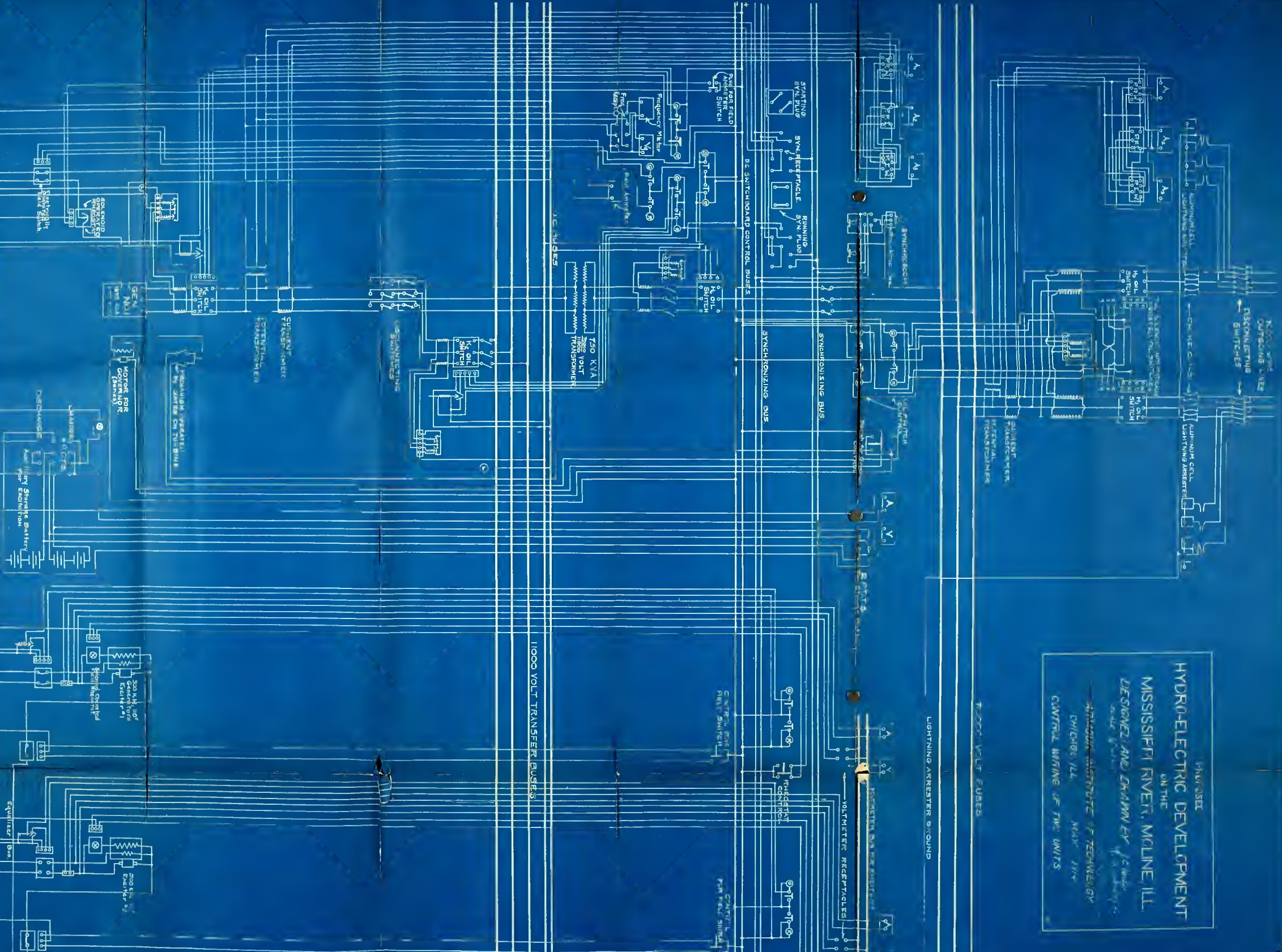




PROJECT  
 HYDRO-ELECTRIC DEVELOPMENT  
 ON THE  
 MISSISSIPPI RIVER, MCLEIN, ILL.  
 LESIGNEZ AND CHAMBERLAIN  
 CHICAGO, ILL.  
 CONTROL WIRING OF TWO UNITS

10000 VOLT FUSES

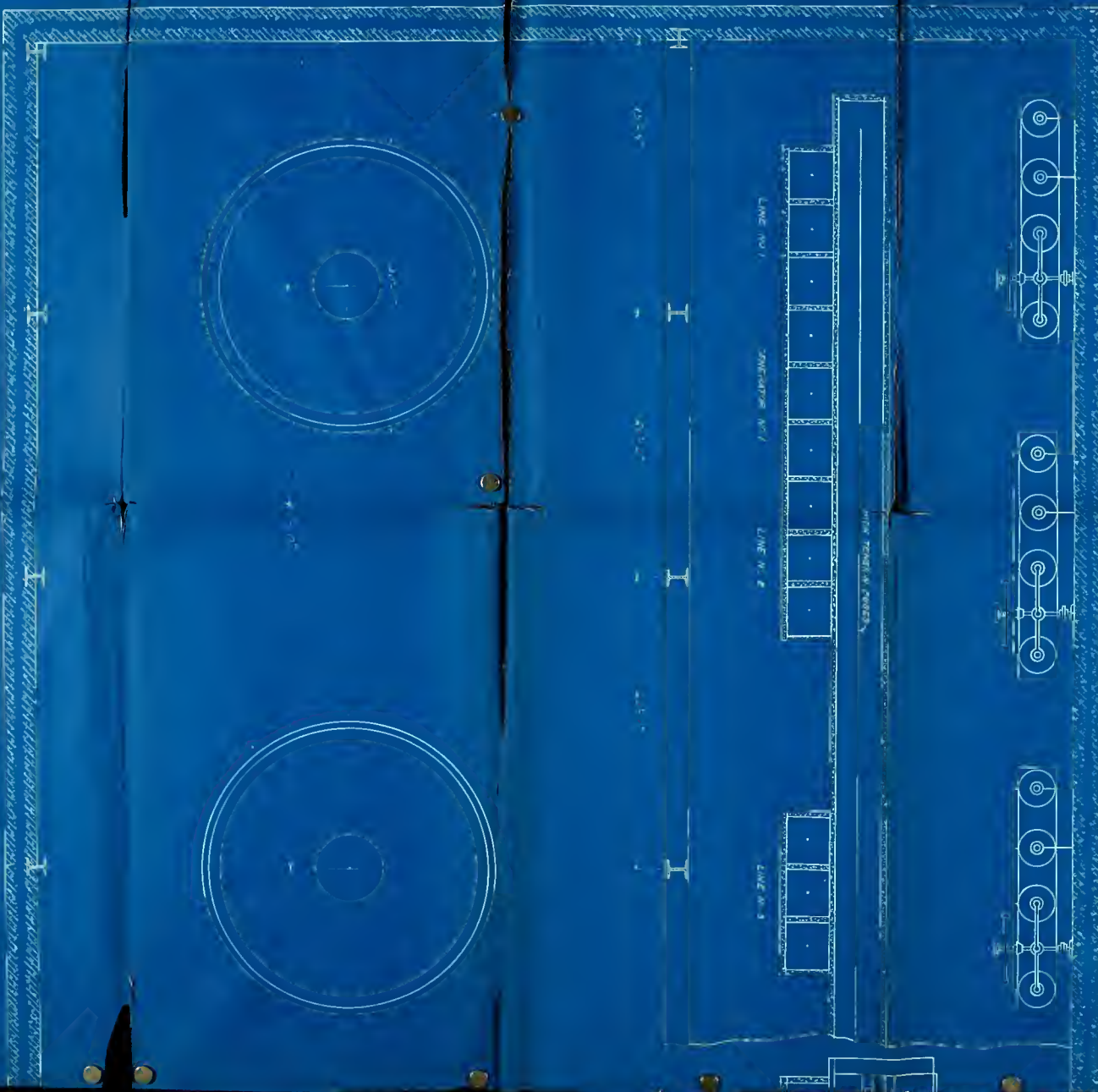
LIGHTNING ARRESTER GROUND



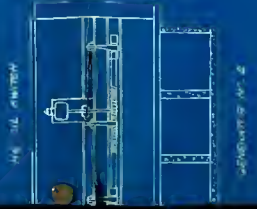
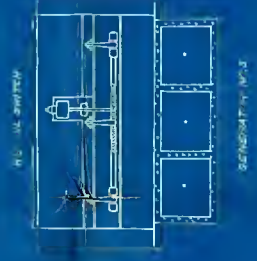
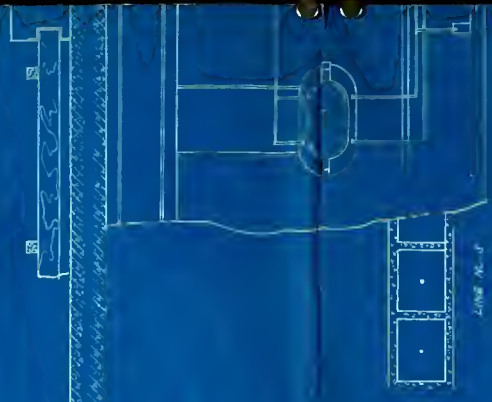
EXCITER BUSES

ADDITION INFORMATION OF INTEREST BY  
CHICAGO ALL MAY 1944  
CONTROL UNITING OF TWO UNITS





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DESIGN  
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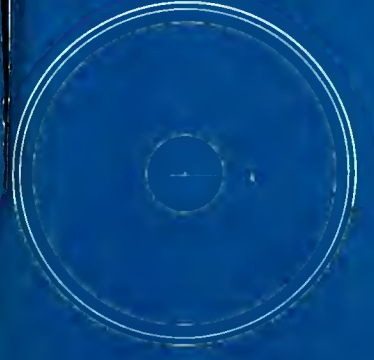


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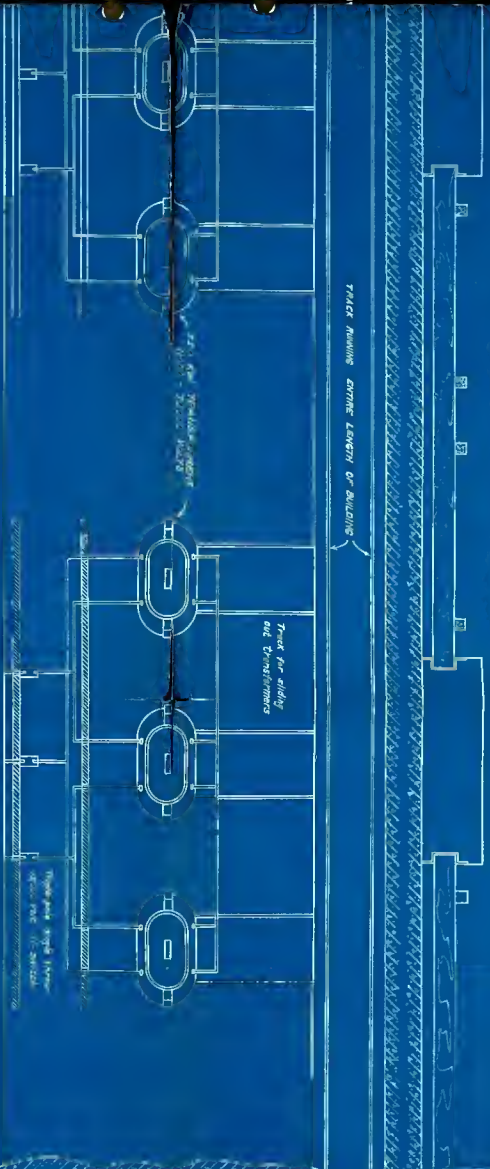
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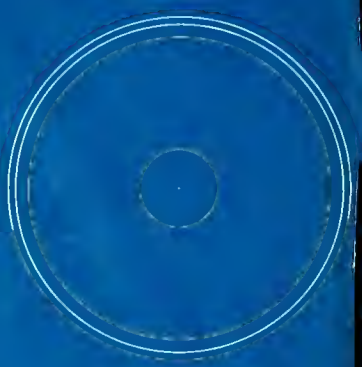
PROPOSED  
ELECTRIC DEVELOPMENT  
ON THE  
SIPPI RIVER, MOJINE ILL.  
RED AND LAMPAN ST.  
13.37  
MODA INSTITUTE OF TECHNOLOGY  
MICHIGAN ILL. MAY 11 1963  
PLAN OF POWER HOUSE



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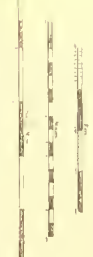
3. GENERATION PANELS

GENERATION DESK



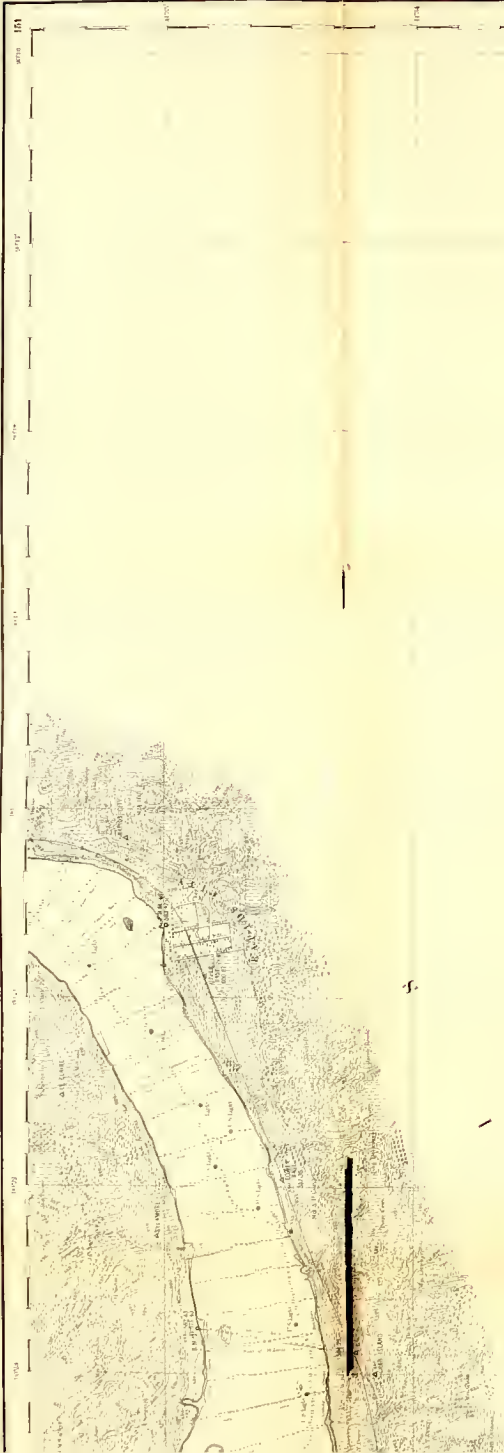


This map is a reproduction of the original map of the Mississippi River Commission, which was published in 1908. The map is a detailed topographical map of the Mississippi River and its tributaries, showing the river's course, its major tributaries, and the surrounding land. The map is oriented with the river flowing from the top left towards the bottom right. The map is divided into several sections, each labeled with a number. The map is a valuable resource for understanding the geography of the Mississippi River and its surrounding areas.



# THE MISSISSIPPI RIVER MISSISSIPPI RIVER COMMISSION (CHART No. 121)





SERIES OF  
**THE MISSISSIPPI RIVER**  
 MISSISSIPPI RIVER COMMISSION  
 CHART NO 161

From all lines a light indicated

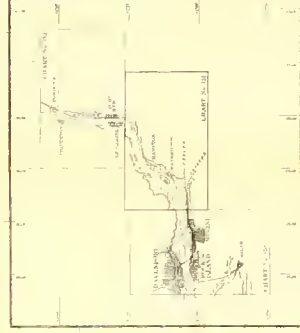
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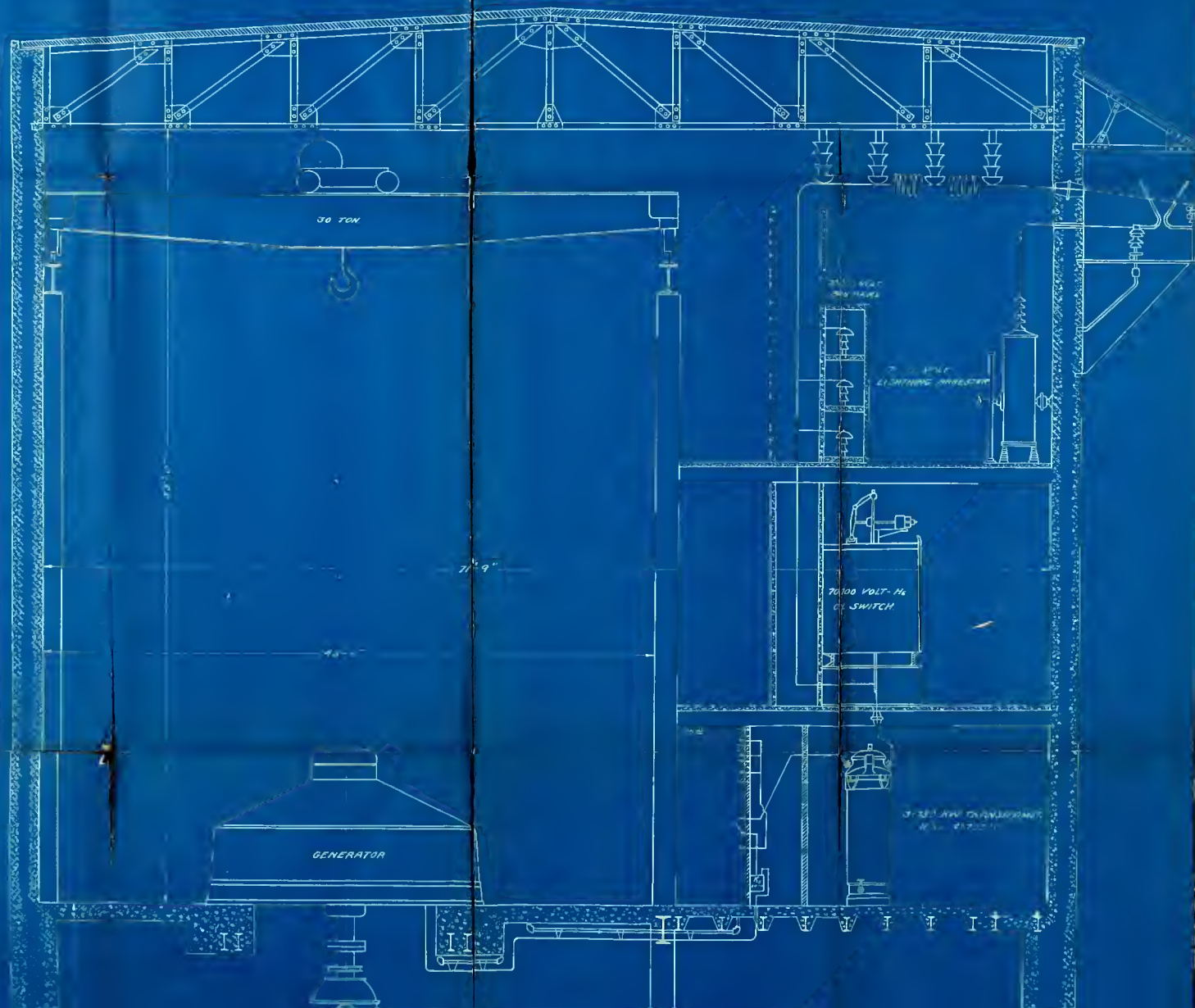
**NOTES**

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**INDEX CHART**



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PROPOSED  
HYDRO-ELECTRIC DEVELOPMENT  
ON THE  
MISSISSIPPI RIVER, MOBILE, ALA.  
DESIGNED BY  
CHAS. E. KERR  
CHICAGO, ILL.  
KERR, SMITH & ASSOCIATES  
CHICAGO, ILL.  
SECTION OF LOWER HOUSE

